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LATEST WIND ESTIMATES FROM 80KM TO 200KM ALTITUDE REGION AT MID-LATITUDES

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ABSTRACT

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The data from a total of forty rocket launches fired specifically to determine wind characteristics by the release of chemiluminescent trails have been compiled and studied in an attempt to clarify seasonal and diurnal trends in upper atmospheric winds above 80 kilometers. From a series of graphs taken at 10-kilometer intervals, a general picture of the change in wind vectors with height is determined.

Below 120 kilometers there appears to be extreme variation in speed and direction with very little correlation with season or time of day discernible. Above 120 kilometers, however, the winds appear to orient more with season, and above 150 kilometers, some diurnal variations become apparent.

More experiments of this type, particularly in the summer and winter months, are needed to establish confidence in the seasonal and diurnal trends.

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SUMMARY

The data from a total of forty rocket launches fired specifically to determine wind characteristics by the release of chemiluminescent trails have been compiled and studied in an attempt to clarify seasonal and diurnal trends in upper atmospheric winds above 80 kilometers. From a series of graphs taken at 10-kilometer intervals, a general picture of the change in wind vectors with height is determined.

Below 120 kilometers there appears to be extreme variation in speed and direction with very little correlation with season or time of day discernible. Above 120 kilometers, however, the winds appear to orient more with season, and above 150 kilometers, some diurnal variations become apparent.

More experiments of this type, particularly in the summer and winter months, are needed to establish confidence in the seasonal and diurnal trends.

I. INTRODUCTION

This paper is a revision to an earlier paper [1] on this subject. The author will present estimates of the wind characteristics from 80 to 200 kilometers based on data which have become available since the publication of TN D-1573. Above two hundred kilometers no detailed estimates of wind flow characteristics will be made due to the lack of data in this region.

The measurement of winds above 200 kilometers by means of ionospheric drifts is, at best, questionable. Since measurements of this type depict only the motions of charged particles, the presence of the earth's magnetic field, as well as electrostatic fields due to ionospheric currents, will undoubtedly distort the overall wind flow characteristics. Based upon this hypothesis, only data obtained by chemiluminescent trails will be presented. A short section (Section IV) will discuss effects of ionospheric winds.

A very promising means of measuring winds by an acoustic method is being developed by the University of Michigan.* In this method rocket booster sound characteristics are recorded at three widely separated

* Under NASA Contract NAS8-11054

ground-based locations, and, when these are subsequently compared on a time of arrival basis, wind speed and direction may be obtained from the shifting of the characteristic sound patterns. This method is, of course, limited to a maximum altitude of about 150 km. The variation of the speed of sound due to temperature differences is a problem that has to be resolved. Another problem area might possibly occur if the sound wave passes through the wake of the vehicle.

The author would like to thank Mr. R. E. Smith, Chief, Space Environment Group, Aero-Astrophysics Office, Aero-Astrodynamic Laboratory for the many helpful suggestions and discussions. In addition, appreciation is extended to Mr. R. B. Owen for the assistance which he has rendered to make this report possible.

II. DISCUSSION

The conclusions drawn from Wasko and Ragsdale [1] will be discussed in the sequence in which they were presented. The first conclusion reached by Wasko and Ragsdale was that the largest variation in wind speed and direction lay between 90 and 125 km. Since the turbulent region of the atmosphere ends at about 110 to 125 kilometers, this conclusion appears correct. According to Rosenberg [2] the equation for the law of diffusion is:

$$r^2 = kt \quad (1)$$

where:

r = radius of expanding vapor trail

k = constant

t = time

This equation accounts for the expansion of trails above 115 km, while from 80-110 km the normal diffusion rate is, at certain points, orders of magnitude larger than predicted by equation (1). Within this turbulent region, the governing equation is more on the order of

$$r^2 = kt^2 \quad (2)$$

according to Zimmerman, Champion, and Rosenberg.

The same authors account for the atmospheric stability above 125 km by assuming that the eddy Reynolds number becomes quite small, and Richardson's number becomes quite large due to the large positive temperature gradient.

Table I indicates the probable horizontal mean wind speed at 10 kilometer intervals from 80 to 200 kilometers. The maximum and the minimum probable horizontal wind speed envelopes are also included, although these are subject to some speculation since they are based upon actual measured values in this data sample.

TABLE I

Height (km)	Minimum Wind Speed (m/s)	Maximum Wind Speed (m/s)	Mean Wind Speed (m/s)
80	5	120	60
90	5	180	65
100	5	200	67
110	5	195	65
120	20	190	75
130	24	180	71
140	10	165	64
150	20	160	74
160	30	162	85
170	38	170	94
180	42	180	102
190	44	190	107
200	45	198	111

The best overall estimate of maximum wind speed in this region is probably 200 meters per second, whereas the probable minimum should be placed around 5 meters per second. A closer analysis of the probable speed envelopes shows that the probable mean profile tends to correspond more closely to the probable minimum than to the probable maximum, perhaps indicating the existence of upper atmospheric "gustiness."

The highest wind shears tend to occur between 85 to 125 kilometers, due to the extreme turbulence in this region. Above 125 kilometers turbulence is probably nonexistent. According to Reference 3, turbulence in winds seems to fall into one of three categories:

- (1) Many small sudden changes take place in the direction of the transport vector with wind speed constantly fluctuating between 30-40 meters per second.
- (2) One 180-degree sudden change in the direction of the transport vector occurs with a velocity range of 0-150 meters per second.
- (3) A slow continuous spiral type change in the direction of the transport vector with the velocity slowly rising to a maximum of about 120 meters per second at a height of around 110 kilometers.

From the general description of these categories, it appears that there is no intermixing of the categories. It has also been noticed that the direction of rotation of the class III winds are clockwise with height similar to the Eckman spiral near the earth's surface; however, no significance has been placed on this finding.

The authors of the report [3] "Study of Winds, Diffusion, and Expansion of Gases in the Upper Atmosphere" have analyzed the diurnal variations of winds by comparing the data of the five flights listed in Table II.

TABLE II

Site	Date and Approximate Local Mean Time		Date and Approximate E.S.T.	
Wallops	4-19-61	04:36	4-19-61	04.6 hr.
Sardinia, Italy	4-19-61	19:12	4-19-61	13.5 hr.
Sardinia, Italy	4-20-61	04:36	4-19-61	22.9 hr.
Wallops	4-20-61	19:12	4-20-61	19.2 hr.
Wallops	4-21-61	04:39	4-21-61	04.6 hr.

Subsequent data have added to these April firings, and the analysis has shown that the time sequenced variations in magnitude and direction vectors of winds at a given altitude correspond to a figure called a limaçon, the general formula being

$$p = b - a \cos \theta$$

where

p = radius

a, b = constants

θ = direction of wind vector

However, the observed limicons do not fit this formula exactly, since they are not symmetrical and are displaced from the origin. The author concludes by saying that the plots are "similar to what might be expected from two out-of-phase, cyclic motions, which in the upper atmosphere, could be due to tidal and heating effects."

According to Newell [10], seasonal variations for middle latitude stations indicate winds predominantly from the east in the summer and from the west in the winter. To determine the diurnal and seasonal trends of winds in various altitude regions, data were compiled and interpolated for 10 kilometer intervals from 80 to 150 kilometers (Figures 1 through 8). The graphs are color-coded for four seasons of the year. Red is for data taken between March 22 and June 21, blue for June 22 to September 21, green for September 22 to December 21, and yellow for the period from December 22 through March 21. Since most of the of the observed trails occurred either at morning or evening twilight, the dashed lines were chosen to represent the former and solid lines the latter.

III. WIND DATA ANALYSIS

Data were collected (Table V) from various reports on a total of forty rocket launches which were made specifically to determine wind data in the upper atmosphere. These data were gathered from graphs of the wind data so that an inherent error of ± 5 degrees in the direction of the transport vector* and ± 2 meters per second in velocity possibly exists. Since some of the reported data were for specific altitudes, some interpolation between data points was also necessary.

Since this analysis will mention the seasonal variations in wind speed and direction, the time period March 22 through June 21 will be referred to as spring; likewise, June 22 through September 21 will be summer, September 22 through December 21, fall and December 22 through March 21, winter.

Figures 1-10 show the data plotted at 10-kilometer intervals from 80-170 kilometers. Figure 11 is a plot of the data for 180, 190, and 200 kilometers in green, red, and blue, respectively.

At 80 kilometers during the interval from March 22 to June 21 (red) the winds are very irregular in both velocity and direction, and, although the points for the interval June 22 through September 21 (blue) are all of relatively low velocity (< 60 m/s) and oriented to the northeast, it is questionable whether any final conclusion can be drawn from these data. Tentatively, however, we will say that winds from July through September tend to be mostly directed to the northeast.

* Direction of transport in the direction toward which the wind is blowing.

From September 22 through December 21, (green) winds once again appear to be variable in speed and direction, but from December 22 to March 21, (yellow) the direction of the winds shows a strong preference for a northerly direction with relatively low velocities.

At 90 kilometers the speeds and directions for spring winds are once again irregular with the velocities ranging from low to medium. Fall winds are also scattered, although the direction of transport for the morning hours seems to be oriented to the southeast while the evening preferred direction seems to be the northeast. The highest velocity and third highest velocity occurred during winter. Although the second highest velocity occurred during fall, the actual date was December 9, which places it very near winter. One might then expect the highest velocity winds at 90 kilometers to occur during the winter months with the direction of transport vector toward the east. Winds toward the west are infrequent and are light when they do occur. This is even more apparent at the 100 kilometer level. During spring and fall, winds may have an occasional westward direction - in the evening during spring and the morning during fall - but the main direction is toward the east. Summer winds tend toward the northeast whereas winter winds are either directed to the north or to the southeast.

At 110 kilometers spring winds remain erratic in both velocity and direction as do the winds during fall. During summer and winter, however, the winds seem to prefer a definitely southern trend with winds for summer being medium to high in velocity directed southeast and winds for winter being light to high directed to the southwest. As one follows summer and winter winds to 120 kilometers, one notices that the preferred direction for the former is now to the southwest with medium to strong winds, and winter winds are directed mostly to the northwest with medium velocities prevailing. It is also worthwhile to note that the preferred direction for all seasons appears to tend toward the west; thus one might expect strong shear effects from 100 to 120 kilometers. At 120 kilometers spring and fall winds remain variable both in speed and direction.

At 130 kilometers, however, this trend appears to change, and spring winds tend to orient themselves to the south or west, with only two morning shots showing winds to the northeast. At this altitude, fall winds seem to remain variable in speed and direction. Summer winds remain westerly, whereas winter winds tend to orient toward the south.

Spring winds continue to orient to the southwest at 140 kilometers. The corresponding velocities appear to increase to medium to strong, with the strongest wind being 168 meters per second occurring during May of 1963. Fall winds likewise begin to show a preferred southeast direction along with winter winds.

At 150 kilometers the north directed winds are completely gone except for one occasion on a morning shot in April of 1962 when a direction of 285° was observed. Spring winds are oriented toward the southwest and winter winds toward the southeast.

Above 150 kilometers there are insufficient data to make any seasonal correlations; however, the winds tend toward a southerly direction with an easterly component preferred for evening winds and a westerly component preferred for morning winds.

A summary of the variation of winds with altitude is given in Table III.

Although no direct correlation could be made with solar activity, there appears to be some correspondence. For a series of days the highest solar activity when compared to the mean seems to generate the higher wind speeds. Table IV gives the magnetic index and sunspot number for the days when data were collected.

According to Jacchia [23] a theory has recently been proposed by Johnson to the effect that the semiannual temperature variation in the thermosphere could be accounted for by assuming convection currents flowing from the summer pole to the winter pole. Although the levels at which this convection is assumed to take place have been around 100 km, it seems noteworthy that the winds above 150 kilometers display this type of trend. Although the winds do show a southerly trend, it should be mentioned that: (1) at 160 kilometers the February and September meridional components were northerly, although the November meridional component was southerly, (2) all April and May meridional components were southerly, and (3) at 180 kilometers and above only the November shot had a distinct northerly component.

IV. IONOSPHERIC WINDS

Winds in the ionosphere have been postulated for some time. The main method by which these winds are studied is by measuring the drift velocities of irregularities in the ionosphere. Rosenberg et al. [19] have attempted to show the correlation of sporadic E with a high wind shear regime by taking ionosondes simultaneously with the chemiluminescent trail reported here for December 3, 1962. Although there was an apparent correlation, more data are required to establish the certainty of such a mechanism.

Alpert et al. [24] have reported an analysis of the movements of ionospheric irregularities in the ionosphere. It is reported that the E layer exhibits a semidiurnal period in the velocity components. Table VI gives the seasonal variations in these components at about 120 Km.

TABLE VI

	<u>N-S COMPONENT</u>	<u>E-W COMPONENT</u>
Spring	30 m/s directed north	50 m/s directed west
Summer	No Analysis	No Analysis
Fall	30 m/s directed north	24 m/s directed east
Winter	~ 40 m/s directed south	50 m/s directed east

In the F_2 region of the ionosphere,* a precise definition of directions and velocities is exceedingly difficult to make. Any charged particle which moves automatically becomes a particle of current and possesses a dipole moment. As a result it is subject to influence put upon it by other ions as well as by the magnetic field of the earth. Since, in the F_2 region of the ionosphere, there are several times the number of charged particles than in the E layer, as well as a considerably lower density, these effects are correspondingly increased.

The diurnal variations in the F_2 region exhibit a westerly direction during the morning hours and an easterly direction in the evening with a slight increase in the velocity during the evening and nighttime hours. At one midlatitude station an analysis of the data showed a northerly component of about 50 m/s and a westerly component of 25 m/s during the fall. For the winter months, the north-south component was directed south at 30 m/s with no prevailing east-west direction and likewise in the spring the meridional component showed a northerly preference of about 30 m/s with no prevailing east-west component.

These wind particles represent on the order of 10^{-4} of the total number of particles present, if we assume that each electron moving in this manner carries with it an associated ion.

* Assumed height of 200 to 400 Kilometers.

CONCLUSIONS

It is apparent that much more data are needed to make a concise analysis of the wind speeds and directions in this region of the atmosphere. Since some correlation was found with the solar flux, a long-range program seems to best fit our need.

There is a special requirement for chemiluminescent trail data for the seasonal gaps left from mid-December to mid-February, and from mid-June to the first of August. In addition, the data for the region from 150 to 200 kilometers are extremely sparse at the present time. There is a great deal more to be learned about the region from 100 to 120 kilometers, since this appears to be an area of extreme turbulence. To understand atmospheric dynamics requires, in addition to knowledge of the wind flow patterns, information on the associated temperature, temperature gradients, density, and composition. For future trajectory and orbital studies which will require relatively precise calculations, it will be necessary to more accurately determine the dynamics of the upper atmosphere. However, the data presented in this report should permit calculations valid as a first approximation and assist in delineating potential design or operational problem areas for planned orbital space vehicle missions.

TABLE III
TIME PERIOD

ALT. (km)	SPRING	SUMMER	FALL	WINTER
80	Variable in velocity and direction.	Velocity less than 60 m/s and directed northeast	Variable in velocity and direction.	Low velocity with predominant northerly component.
90	Variable with some easterly predominance velocity variable.	Insufficient data	Variable velocity with preferred southeast in the a.m. and northeast in the p.m.	Variable velocity with a preferred easterly component.
100	Variable velocity with predominance to the east, especially in the morning.	Insufficient data	Variable in velocity and direction, but with p.m. data favoring northeast.	Variable velocity with an easterly preference.
110	Variable in velocity and direction.	Southeast direction with medium velocities.	Variable in velocity and direction.	Medium to high velocity with a southwest heading.
120	Variable velocity and direction.	Medium to high velocity directed to the southwest.	Variable direction with a southern morning trend. Velocities light to medium.	Medium velocities directed to the west.

TABLE III (Continued)

ALT. (km)	SPRING	SUMMER	FALL	WINTER
130	Medium to high velocity with a preferred southerly or westerly direction.	Variable velocities with a predominant westerly component.	Probable medium velocities directed to the south.	Variable in velocity but tending toward a southerly heading.
140	Velocities ranging from low to high with a strong southern and western preference.	Variable velocities with morning heading southwest and evening northeast.	Variable velocity with southeast direction.	Variable velocities with a southeast preference.
150	Light to high velocity winds directed to the southwest.	Insufficient data	Low to medium velocities in a southern direction.	Low to high velocities directed to the south-east.
160	Morning shots prefer a southwesterly direction whereas the evening winds tend toward the south and east.			
170	Morning winds prefer south and west components whereas evening winds prefer south and east components.			
180 190 200	All morning winds have a southerly and westerly preference, and all evening winds have southerly and easterly preferences. All velocities above 150 km are medium to high with the morning velocities being higher.			

TABLE IV

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Magnetic</u> <u>Index</u>	<u>Sunspot</u> <u>Number</u>
April 11, 1956	E	3+	197
August, 17, 1959	M	7-	166
September 29, 1959	M	2.0	87
September 30, 1959	M	2-	86
October 3, 1959	M	4.0	89
November 18, 1959	E	3.0	73
February 27, 1960	M	3+	92
April 1, 1960	E	9-	154
May 24, 1960	E	3+	147
May 31, 1960	E	3.0	111
August 9, 1960	M	5-	76
August 10, 1960	M	4-	94
August 13, 1960	M	2-	235
August 16, 1960	M	1-	244
August 17, 1960	M	7.0	253
August 18, 1960	M	4-	257
December 9, 1960	M	3+	97
April 1, 1961	E	2-	87
April 19, 1961	E & M	2.0 & 2.0	65
April 20, 1961	E & M	2.0 & 1.0	56
April 21, 1961	M	0+	52
September 16, 1961	E	1+	102
September 17, 1961	M	4+	84
March 1, 1962	E	3-	74
March 2, 1962	M	2.0	66
March 23, 1962	E	1-	84

TABLE IV (Continued)

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Magnetic</u> <u>Index</u>	<u>Sunspot</u> <u>Number</u>
March 27, 1962	E	1.0	48
April 17, 1962	M	3+	86
June 6, 1962	E	1+	33
November 7, 1962	M	4-	12
November 30, 1962	M	2.0	10
December 3, 1962	E	1.0	37
December 5, 1962	E	2-	43
February 20, 1963	E	2-	20
February 21, 1963	E	3-	19
May 17, 1963	E	2+	74
May 18, 1963	M	0+	85
May 21, 1964	E	1.0	49

TABLE V
80 Kilometers

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Velocity</u>	<u>Direction of</u> <u>Transport</u>
April 11, 1956	E	109	100°
August 9, 1960	M	35	45°
May 21, 1963	E	30	350°
February 27, 1960	E	30	35°
April 1, 1960	E	30	250°
March 1, 1962	E	47	20°
March 2, 1962	M	8	300°
March 23, 1962	E	48	140°
March 27, 1962	E	88	190°
April 17, 1962	M	8	210°
June 6, 1962	E	53	210°
November 7, 1962	M	55	100°
November 30, 1962	M	71	35°
September 16, 1961	E	57	60°
February 20, 1963	E	48	25°
May 17, 1963	E	65	285°
August 13, 1960	M	40	50°

TABLE V (Continued)

90 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
December 3, 1962	E	40 m/s	260°
May 17, 1963	E	70 m/s	35°
May 24, 1960	E	62 m/s	105°
December 9, 1960	M	120 m/s	75°
April 19, 1961	E	21 m/s	70°
April 20, 1961	E	40 m/s	210°
April 21, 1961	M	30 m/s	180°
September 16, 1961	E	70 m/s	10°
February 27, 1960	E	140 m/s	55°
April 1, 1960	E	35 m/s	35°
May 31, 1960	E	58 m/s	196°
February 21, 1963	E	40 m/s	130°
February 20, 1963	E	102 m/s	80°
November 30, 1962	M	72 m/s	120°
December 5, 1962	E	43 m/s	5°
November 7, 1962	M	38 m/s	195°
June 6, 1962	E	5 m/s	10°
April 17, 1962	M	42 m/s	45°
March 27, 1962	E	10 m/s	335°
March 23, 1962	E	25 m/s	50°
March 2, 1962	M	22 m/s	55°
March 1, 1962	E	19 m/s	285°
May 21, 1963	E	68 m/s	85°

TABLE V (Continued)

100 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
May 21, 1963	E	59 m/s	70°
March 1, 1962	E	33 m/s	15°
March 2, 1962	M	77 m/s	10°
March 23, 1962	E	52 m/s	65°
March 27, 1962	E	50 m/s	300°
April 17, 1962	M	95 m/s	75°
June 6, 1962	E	121 m/s	110°
November 7, 1962	M	40 m/s	340°
December 5, 1962	E	84 m/s	60°
November 30, 1962	M	15 m/s	250°
February 20, 1963	E	70 m/s	100°
February 21, 1963	E	31 m/s	170°
February 27, 1960	E	19 m/s	340°
April 1, 1961	E	108 m/s	125°
May 31, 1960	E	46 m/s	320°
May 24, 1960	E	72 m/s	110°
December 9, 1960	M	57 m/s	145°
April 19, 1961	M	38 m/s	170°
April 19, 1961	E	80 m/s	60°
April 20, 1961	E	40 m/s	60°
April 21, 1961	M	55 m/s	85°
September 16, 1961	E	93 m/s	30°
September 17, 1961	M	39 m/s	115°
November 18, 1959	E	98 m/s	60°
August 16, 1960	M	95 m/s	90°
December 3, 1962	E	100 m/s	85°
May 17, 1963	E	95 m/s	210°
May 18, 1963	M	38 m/s	180°

TABLE V (Continued)

110 Kilometers

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Speed</u>	<u>Direction</u>
December 3, 1962	E	57 m/s	255°
May 17, 1963	E	112 m/s	350°
May 18, 1963	M	82 m/s	270°
August 18, 1960	M	64 m/s	110°
August 10, 1960	M	60 m/s	150°
October 3, 1959	M	75 m/s	240°
September 29, 1959	M	145 m/s	210°
November 18, 1959	E	34 m/s	75°
May 24, 1960	E	19 m/s	200°
December 9, 1960	M	85 m/s	55°
April 19, 1961	M	107 m/s	100°
April 19, 1961	E	85 m/s	165°
April 20, 1961	M	30 m/s	70°
April 20, 1961	E	60 m/s	115°
April 21, 1961	M	45 m/s	355°
September 16, 1961	E	110 m/s	170°
September 17, 1961	M	5 m/s	220°
March 1, 1962	E	101 m/s	210°
March 2, 1962	M	77 m/s	215°
March 23, 1962	E	49 m/s	60°
March 27, 1962	E	50 m/s	320°
April 17, 1962	M	128 m/s	135°
June 6, 1962	E	42 m/s	290°

TABLE V (Continued)
110 Kilometers (Continued)

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Speed</u>	<u>Direction</u>
November 7, 1962	M	95 m/s	5°
December 5, 1962	E	42 m/s	165°
November 30, 1962	M	64 m/s	220°
February 20, 1963	E	144 m/s	230°
February 21, 1963	E	50 m/s	180°
May 21, 1963	E	40 m/s	240°

TABLE V (Continued)

120 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
May 21, 1963	E	33 m/s	260°
March 1, 1962	E	102 m/s	260°
March 2, 1962	M	42 m/s	305°
March 23, 1962	E	105 m/s	175°
April 17, 1962	M	71 m/s	200°
June 6, 1962	E	60 m/s	60°
November 7, 1962	M	64 m/s	165°
December 5, 1962	E	27 m/s	85°
November 30, 1962	M	37 m/s	155°
February 20, 1963	E	72 m/s	325°
February 21, 1963	E	52 m/s	285°
May 24, 1960	E	148 m/s	270°
December 9, 1960	M	62 m/s	195°
April 19, 1961	M	75 m/s	160°
April 19, 1961	E	64 m/s	270°
April 20, 1961	M	50 m/s	205°
April 20, 1961	E	37 m/s	165°
April 21, 1961	M	37 m/s	165°
September 16, 1961	E	95 m/s	270°
September 17, 1961	M	55 m/s	240°
November 18, 1959	E	24 m/s	260°
December 3, 1962	E	50 m/s	315°
May 17, 1963	E	93 m/s	15°
May 18, 1963	M	92 m/s	350°
August 17, 1960	M	162 m/s	230°
September 30, 1959	M	55 m/s	275°

TABLE V (Continued)

130 Kilometers

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Speed</u>	<u>Direction</u>
May 21, 1963	E	31 m/s	295°
December 3, 1962	E	18 m/s	40°
May 17, 1963	E	155 m/s	175°
May 18, 1963	M	66 m/s	20°
November 18, 1959	E	37 m/s	185°
May 24, 1960	E	78 m/s	290°
December 9, 1960	M	58 m/s	225°
April 19, 1961	M	66 m/s	30°
April 19, 1961	E	70 m/s	270°
April 20, 1961	M	45 m/s	215°
April 20, 1961	E	95 m/s	180°
April 21, 1961	M	93 m/s	150°
September 16, 1961	E	88 m/s	310°
September 17, 1961	M	32 m/s	230°
March 23, 1962	E	105 m/s	205°
April 17, 1962	M	77 m/s	275°
June 6, 1962	E	100 m/s	190°
November 7, 1962	M	57 m/s	260°
December 5, 1962	E	104 m/s	25°
November 30, 1962	M	57 m/s	260°
February 20, 1963	E	31 m/s	100°
February 21, 1963	E	39 m/s	240°

TABLE V (Continued)

140 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
March 23, 1962	E	116 m/s	225°
April 17, 1962	M	69 m/s	305°
November 7, 1962	M	46 m/s	180°
December 5, 1962	E	45 m/s	120°
November 30, 1962	M	112 m/s	150°
February 20, 1963	E	82 m/s	140°
February 21, 1963	E	29 m/s	180°
May 24, 1960	E	43 m/s	270°
April 19, 1961	M	62 m/s	140°
April 19, 1961	E	59 m/s	235°
April 20, 1961	M	58 m/s	210°
April 20, 1961	E	100 m/s	170°
April 21, 1961	M	93 m/s	185°
September 16, 1961	E	54 m/s	40°
September 17, 1961	M	53 m/s	225°
November 18, 1959	E	91 m/s	160°
May 17, 1963	E	168 m/s	190°
May 18, 1963	M	15 m/s	90°
May 21, 1963	E	15 m/s	315°

TABLE V (Continued)

150 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
May 17, 1963	E	150 m/s	195°
May 18, 1963	M	33 m/s	165°
November 18, 1959	E	79 m/s	135°
April 19, 1961	M	50 m/s	190°
April 19, 1961	E	71 m/s	180°
April 20, 1961	M	94 m/s	215°
April 20, 1961	E	128 m/s	200°
April 21, 1961	M	75 m/s	210°
September 17, 1961	M	67 m/s	260°
April 17, 1962	M	78 m/s	285°
November 7, 1962	M	32 m/s	220°
November 30, 1962	M	96 m/s	160°
February 20, 1963	E	132 m/s	165°
February 21, 1963	E	37 m/s	95°

TABLE V (Continued)

160 Kilometers

<u>Date</u>	<u>Morning (M)</u> <u>or</u> <u>Evening (E)</u>	<u>Speed</u>	<u>Direction</u>
April 17, 1962	M	85 m/s	270°
February 21, 1963	E	45 m/s	55°
April 19, 1961	E	88 m/s	180°
April 20, 1961	M	123 m/s	215°
April 20, 1961	E	118 m/s	185°
April 21, 1961	M	56 m/s	220°
September 17, 1961	M	109 m/s	295°
November 18, 1959	E	59 m/s	120°
May 17, 1963	E	97 m/s	205°
May 18, 1963	M	59 m/s	180°

170 Kilometers

November 18, 1959	E	55 m/s	85°
August 17, 1959	M	188 m/s	225°
April 19, 1961	E	119 m/s	180°
April 20, 1961	M	135 m/s	220°
September 17, 1961	M	95 m/s	310°
April 17, 1962	M	92 m/s	270°

TABLE V (Continued)

180 Kilometers

<u>Date</u>	<u>Morning (M)</u>	<u>Speed</u>	<u>Direction</u>
	<u>or</u> <u>Evening (E)</u>		
April 17, 1962	M	97 m/s	280°
April 19, 1961	E	141 m/s	170°
April 20, 1961	M	135 m/s	225°
November 18, 1959	E	54 m/s	65°
August 17, 1959	M	168 m/s	225°

190 Kilometers

April 17, 1962	M	107 m/s	280°
April 20, 1961	M	135 m/s	230°
November 18, 1959	E	53 m/s	50°
August 17, 1959	M	157 m/s	225°

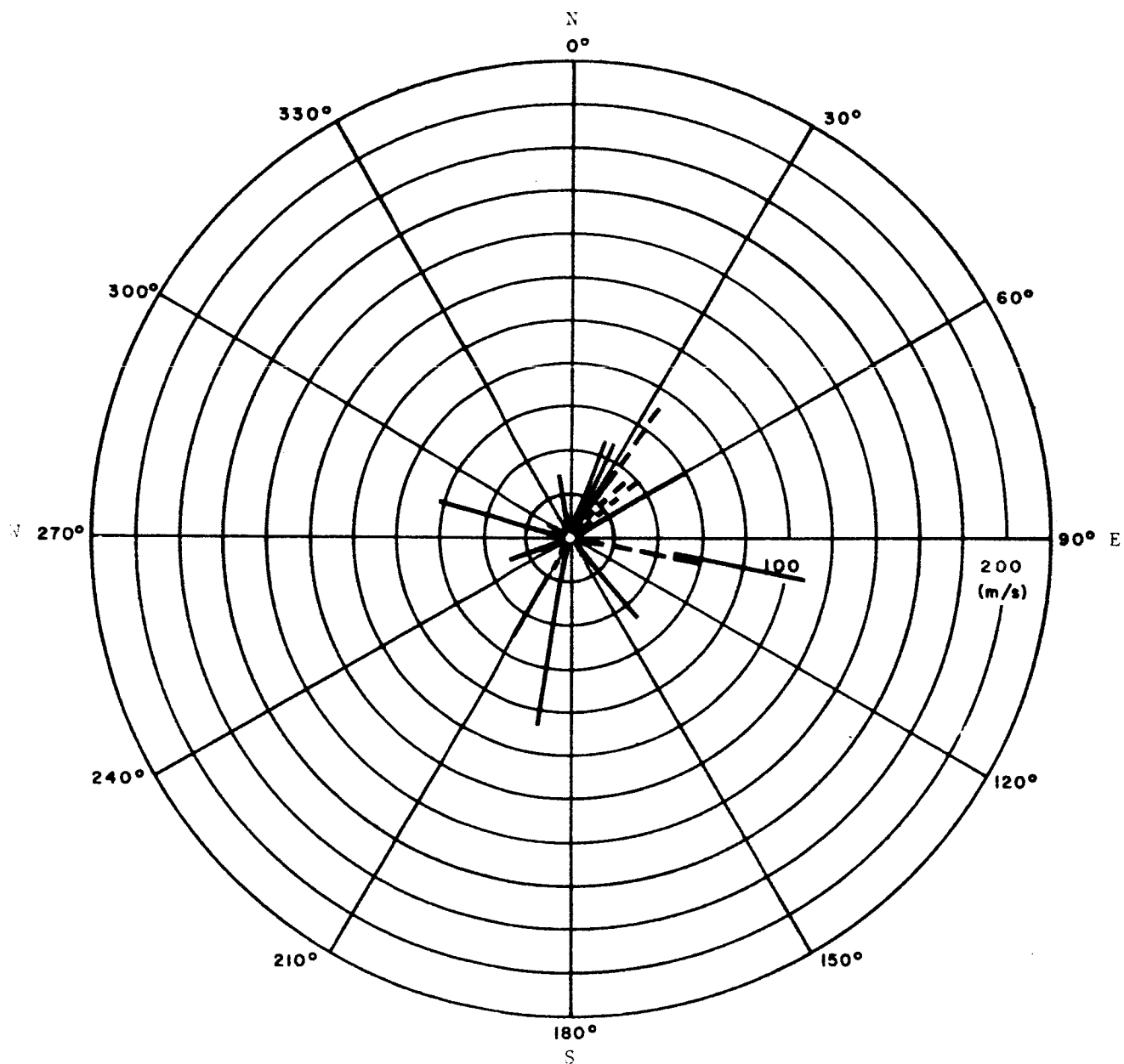
200 Kilometers

November 18, 1959	E	54 m/s	35°
August 17, 1959	M	137 m/s	220°

LEGEND

Mar 22 - Jun 21
 Sep 22 - Dec 21
 Jun 22 - Sep 21
 Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 1. WIND VELOCITIES AND DIRECTIONS AT 80 KILOMETERS

LEGEND

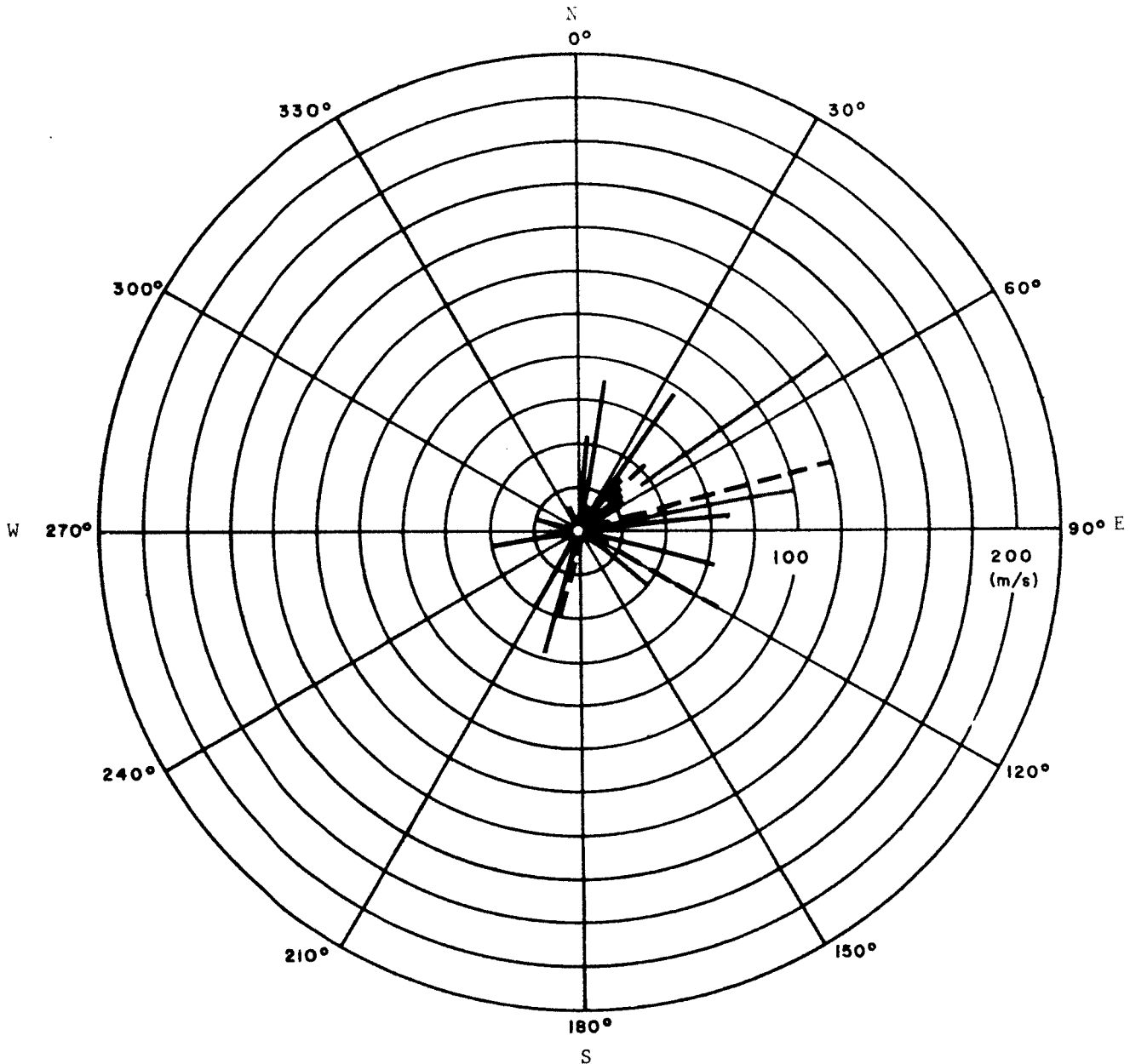
Mar 22 - Jun 21

Sep 22 - Dec 21

Jun 22 - Sep 21

Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



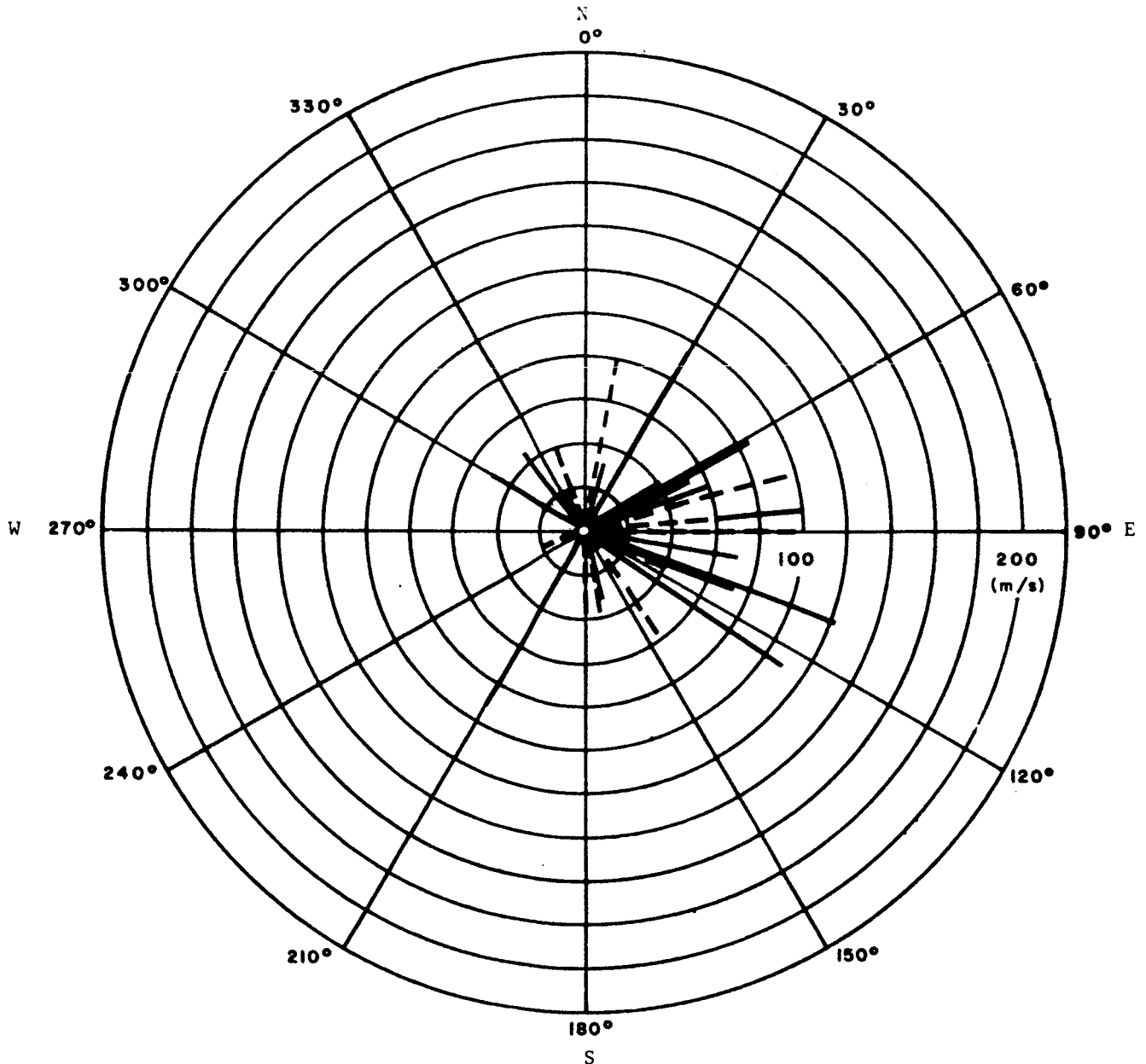
NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 2. WIND VELOCITIES AND DIRECTIONS AT 90 KILOMETERS

LEGEND

———— Mar 22 - Jun 21	———— Sep 22 - Dec 21
———— Jun 22 - Sep 21	———— Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



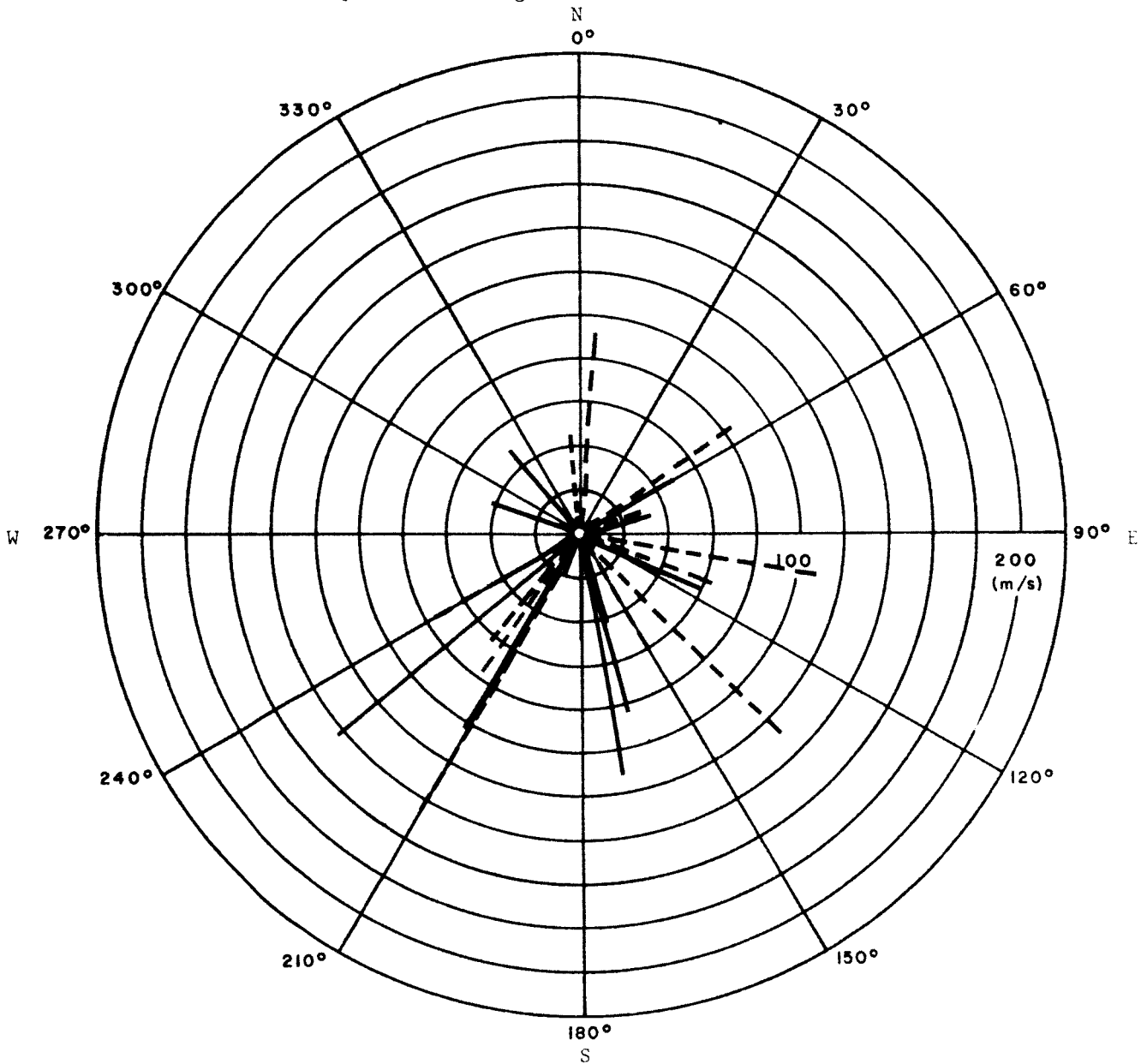
NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 3. WIND VELOCITIES AND DIRECTIONS AT 100 KILOMETERS

LEGEND

 Mar 22 - Jun 21	 Sep 22 - Dec 21
 Jun 22 - Sep 21	 Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 4. WIND VELOCITIES AND DIRECTIONS AT 110 KILOMETERS

LEGEND

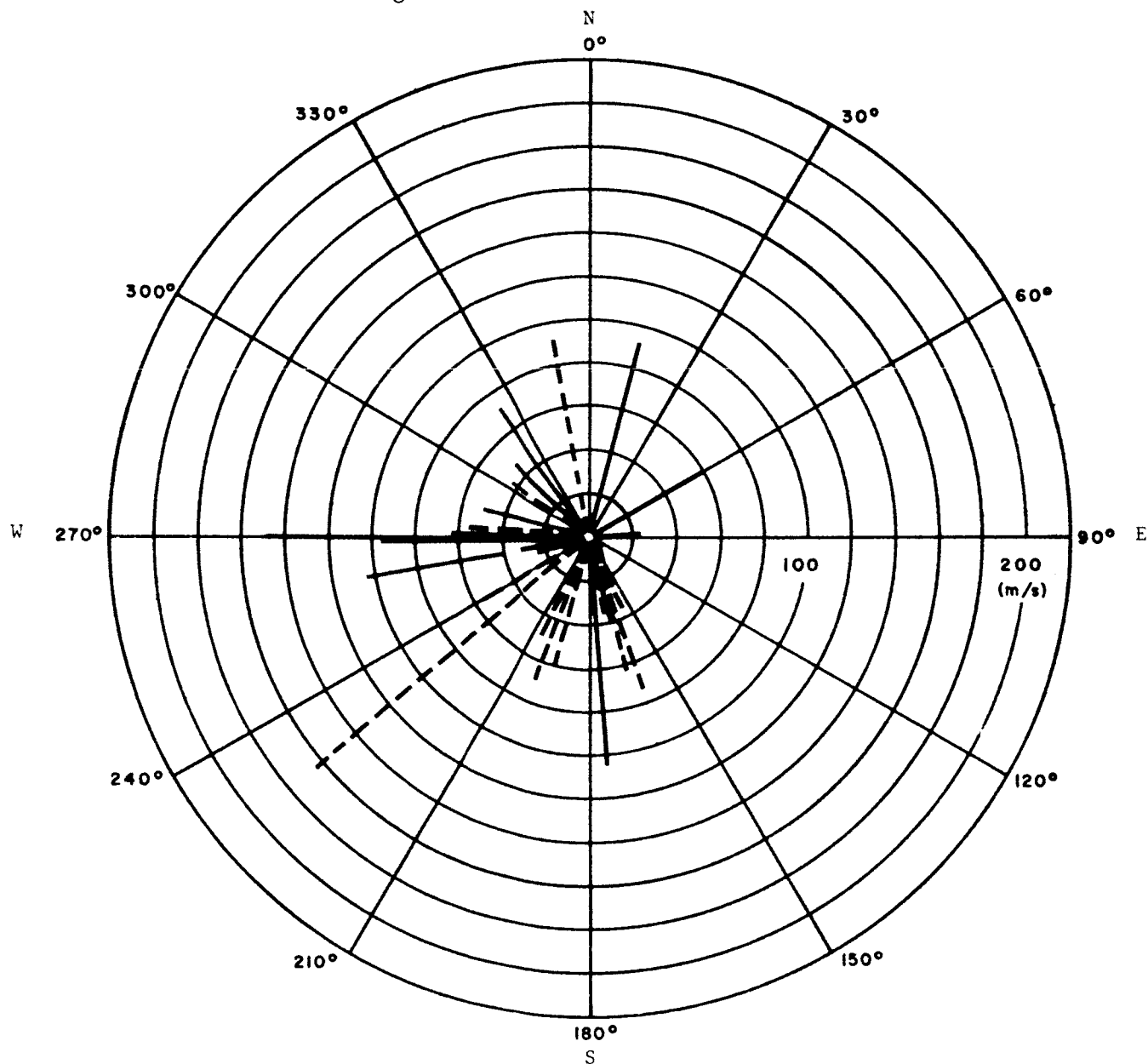
Mar 22 - Jun 21

Sep 22 - Dec 21

Jun 22 - Sep 21

Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 5. WIND VELOCITIES AND DIRECTIONS AT 120 KILOMETERS

LEGEND

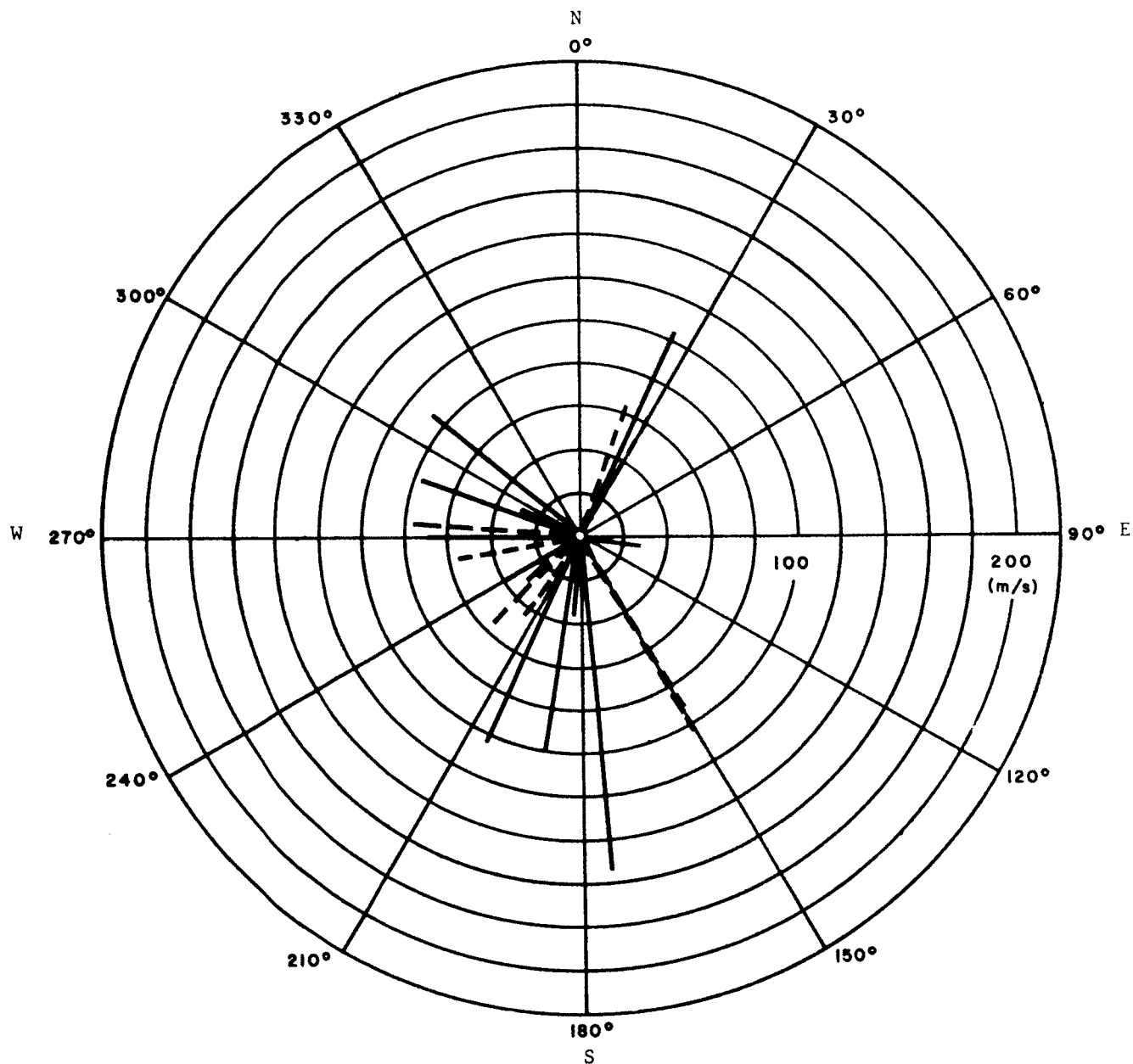
Mar 22 - Jun 21

Sep 22 - Dec 21

Jun 22 - Sep 21

Dec 22 - Mar 21


Dashed lines represent morning winds; solid lines represent evening winds.



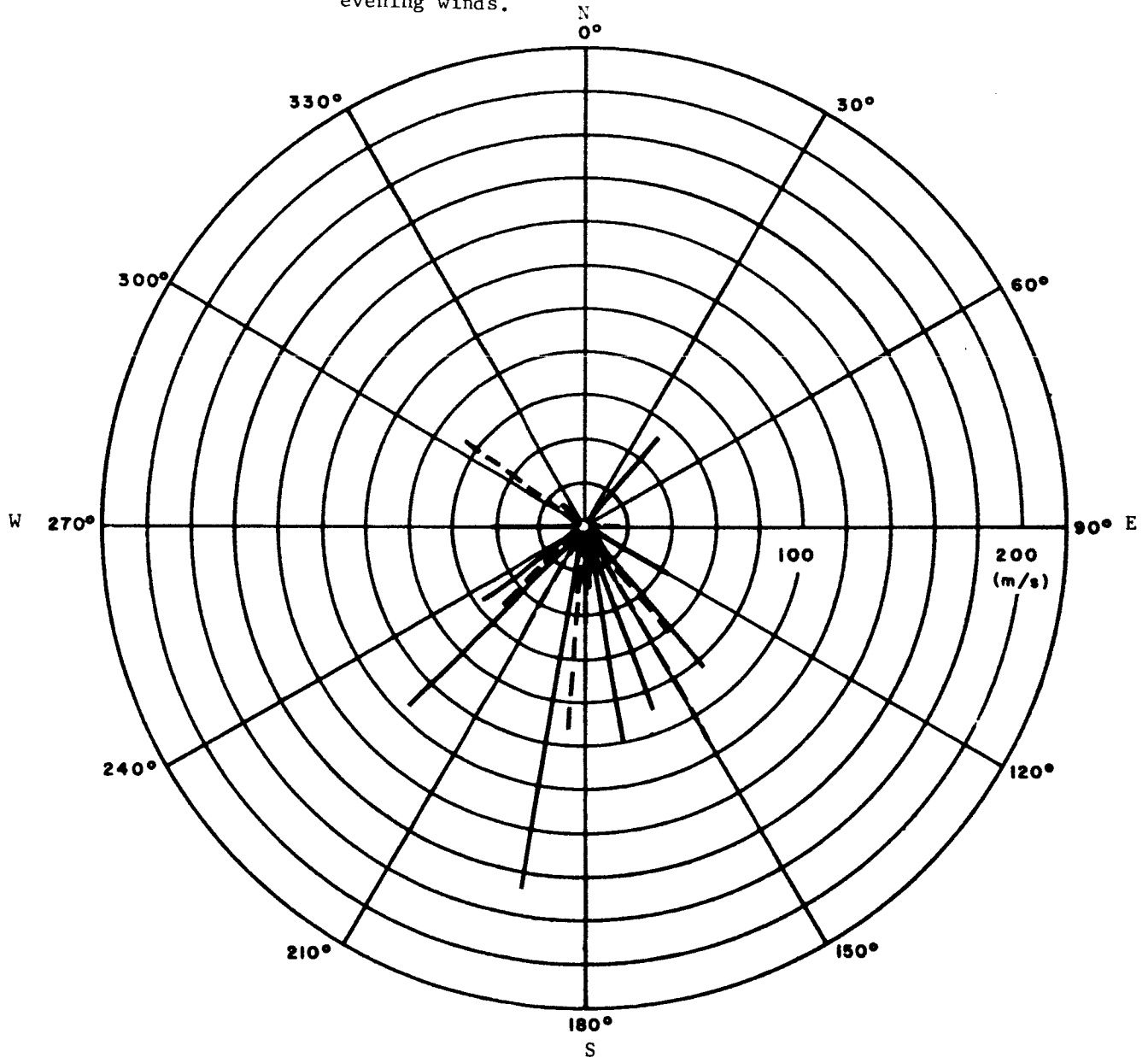
NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 6. WIND VELOCITIES AND DIRECTIONS AT 130 KILOMETERS

LEGEND

	Mar 22 - Jun 21		Sep 22 - Dec 21
	Jun 22 - Sep 21		Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.



NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 7. WIND VELOCITIES AND DIRECTIONS AT 140 KILOMETERS

LEGEND

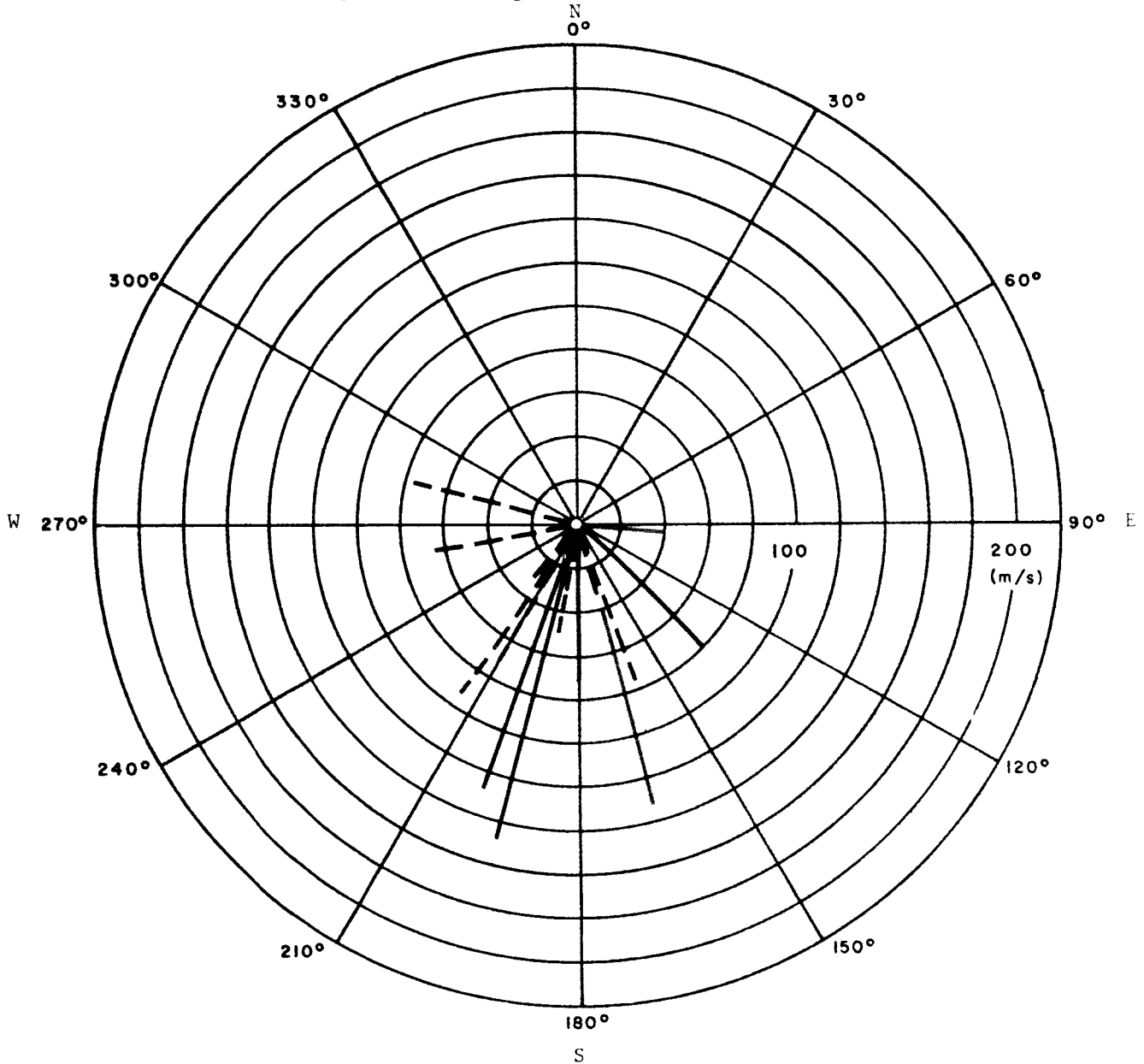
Mar 22 - Jun 21

Sep 22 - Dec 21

Jun 22 - Sep 21

Dec 22 - Mar 21

Dashed lines represent morning winds; solid lines represent evening winds.

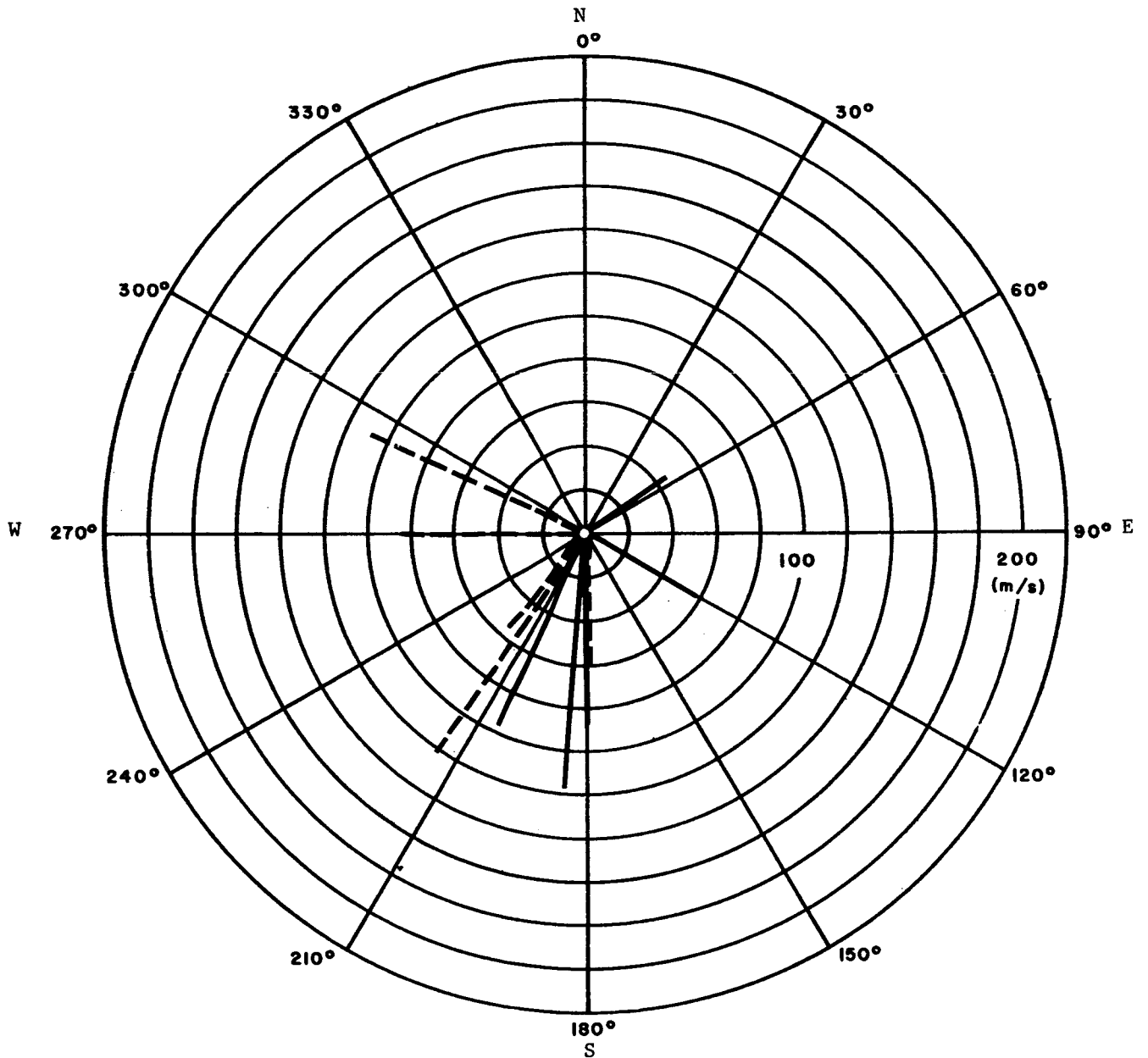


NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 8. WIND VELOCITIES AND DIRECTIONS AT 150 KILOMETERS

LEGEND

Dashed lines represent morning winds while
solid lines represent evening winds.

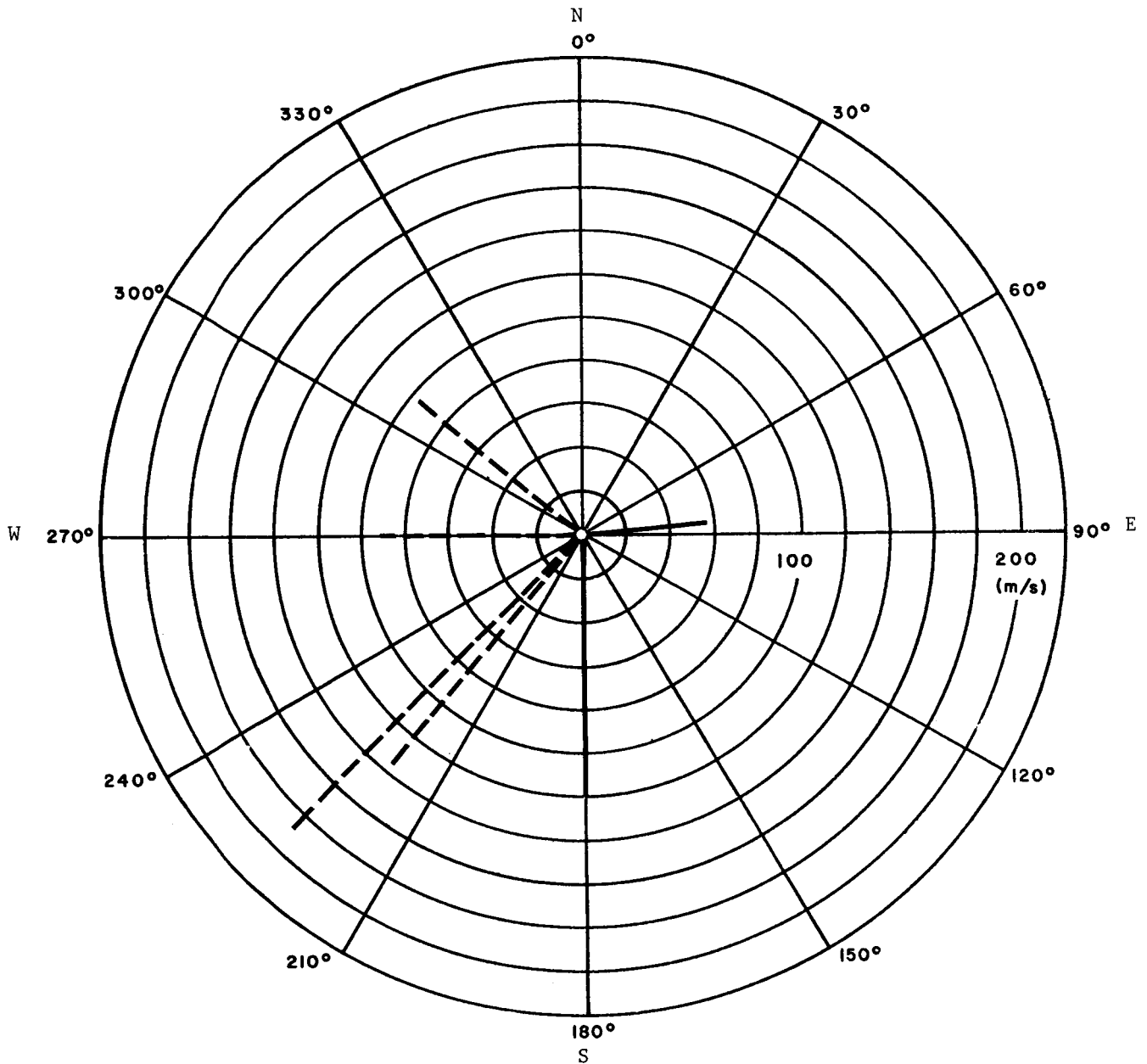


NOTE: Directions are direction of transport, or direction toward which the
wind is blowing.

FIGURE 9. WIND VELOCITIES AND DIRECTIONS AT 160 KILOMETERS

LEGEND

Dashed lines represent morning winds while
solid lines represent evening winds.



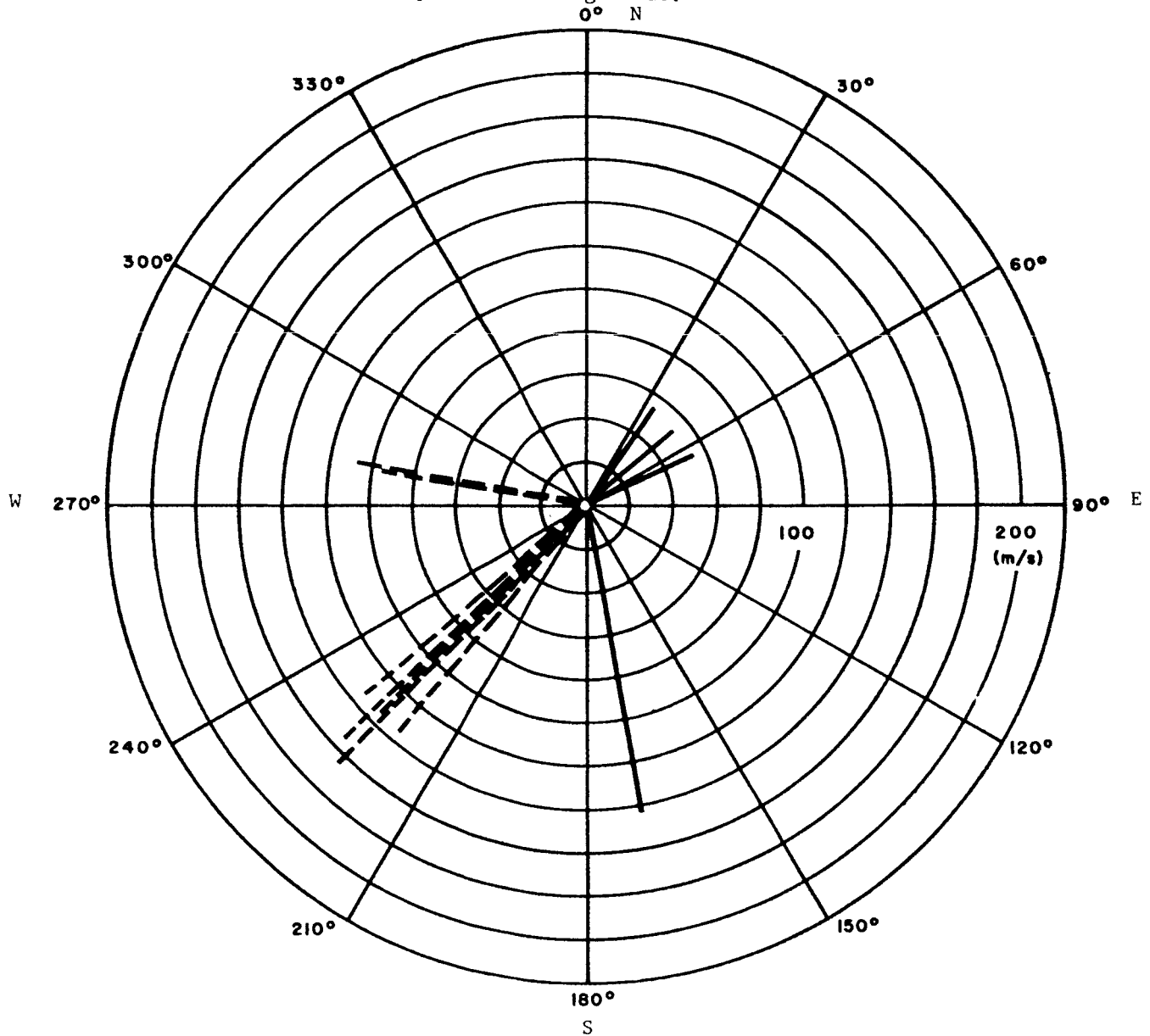
NOTE: Directions are direction of transport, or direction toward which
the wind is blowing.

FIGURE 10. WIND VELOCITIES AND DIRECTIONS AT 170 KILOMETERS

LEGEND

- Winds at 180 Kilometers
- Winds at 190 Kilometers
- Winds at 200 Kilometers

Dashed lines represent morning winds while solid lines represent evening winds.



NOTE: Directions are direction of transport, or direction toward which the wind is blowing.

FIGURE 11. WIND VELOCITIES AND DIRECTIONS AT 180, 190 AND 200 KILOMETERS

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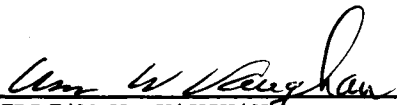
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